INDIVIDUAL NANOPARTICLE SIZE and COMPOSITION by REAL-TIME MASS-SPECTROSCOPY
and
THERMODYNAMICS and KINETICS on the NANOSCALE

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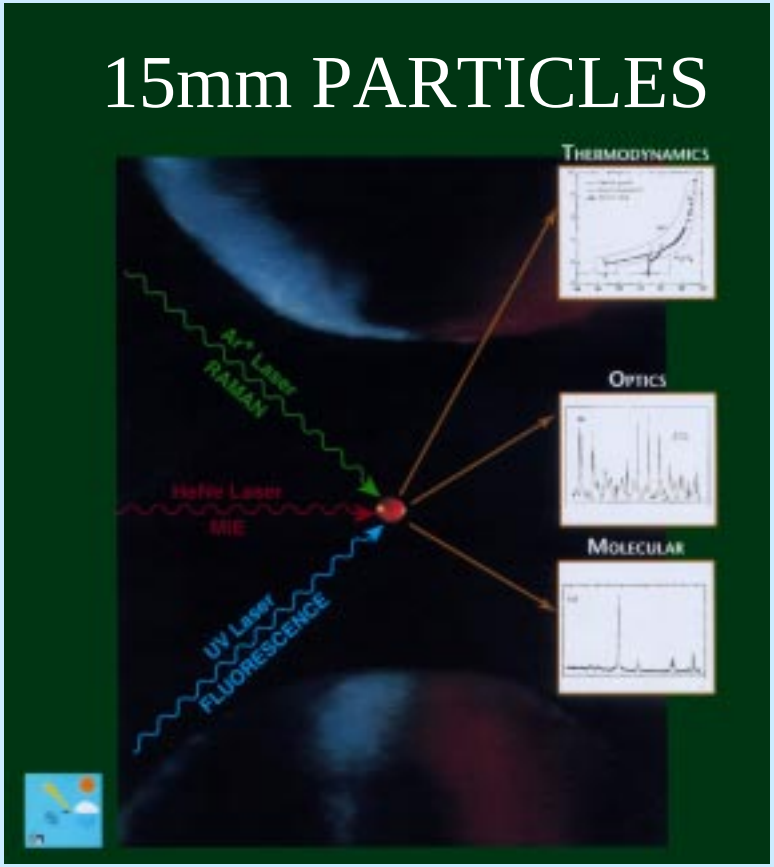
WHERE WE WERE ~2.5YEARS AGO

Science

- Mie scattering
- Thermodynamics
- Nucleation dynamics

Analytical

- Raman spectroscopy



WHERE WE ARE TODAY

Science

- A system for the study of thermodynamics and kinetics in particles as small as 4nm has been constructed and demonstrated.

Analytical

- The BNL Single Particle Laser Ablation Time of Flight Mass Spectrometer (SPLAT-MS) can size and obtain chemical composition of individual particles down to 50nm.

ROAD MAP

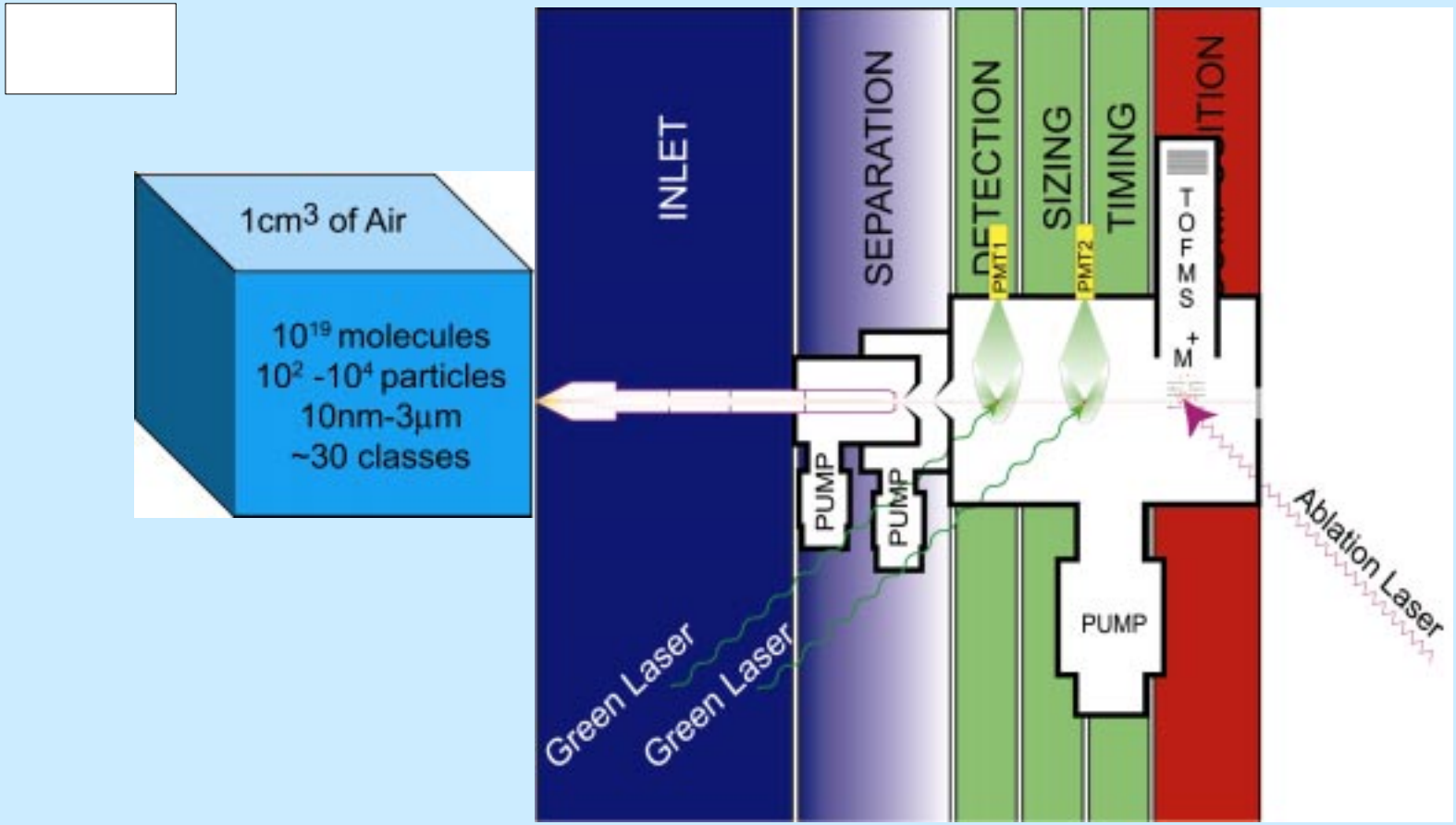
- SPLAT-MS
  - Basics
  - Where it has been: Preliminary results from Houston
  - Where we are going with it

- Thermodynamics and kinetics on the nanoscale
  - The system
  - Very recent results
  - Where we are going with it

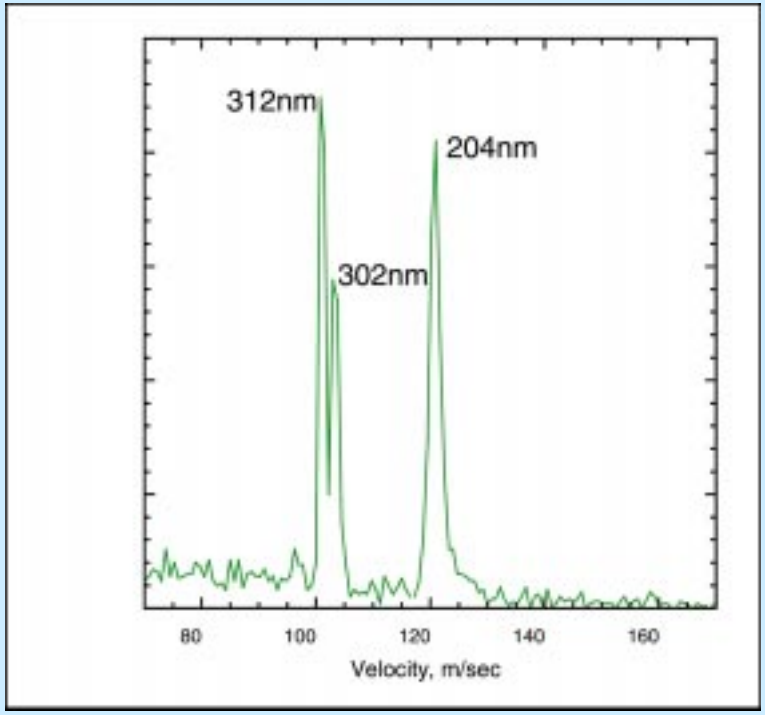
SPLAT-MS APPLICATIONS

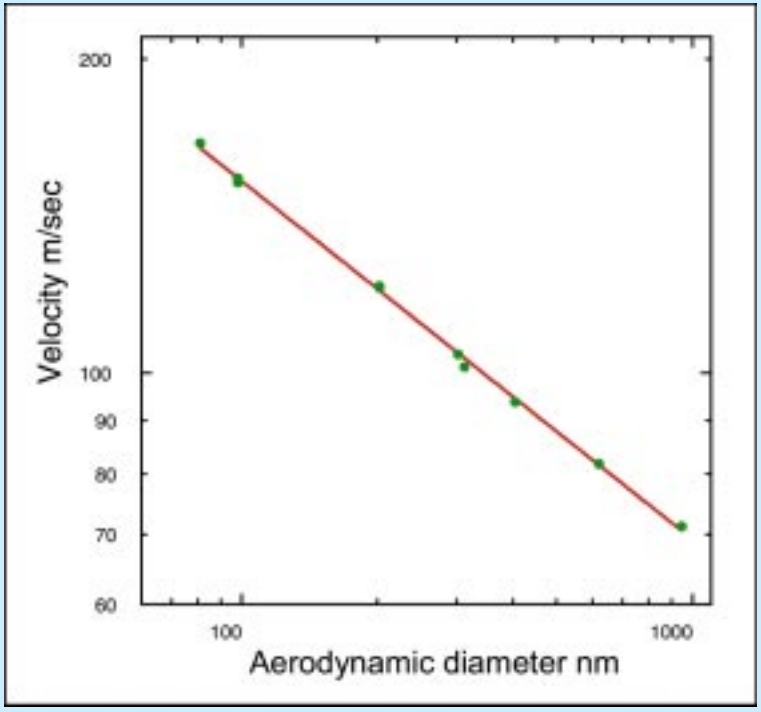
- Atmospheric aerosols (OBER/ACP/TAP)
- Aerosol production by combustion processes (BES/CHEM)
- Aerosols and diesel engines (Fossil Energy)
- Biochemical agent detection (DOE, DOD, …)
- Monitoring semiconductor manufacture (Bell Labs)
- NOAA/NSF funded program
- EPA funded program

SPLAT-MS the BASICS

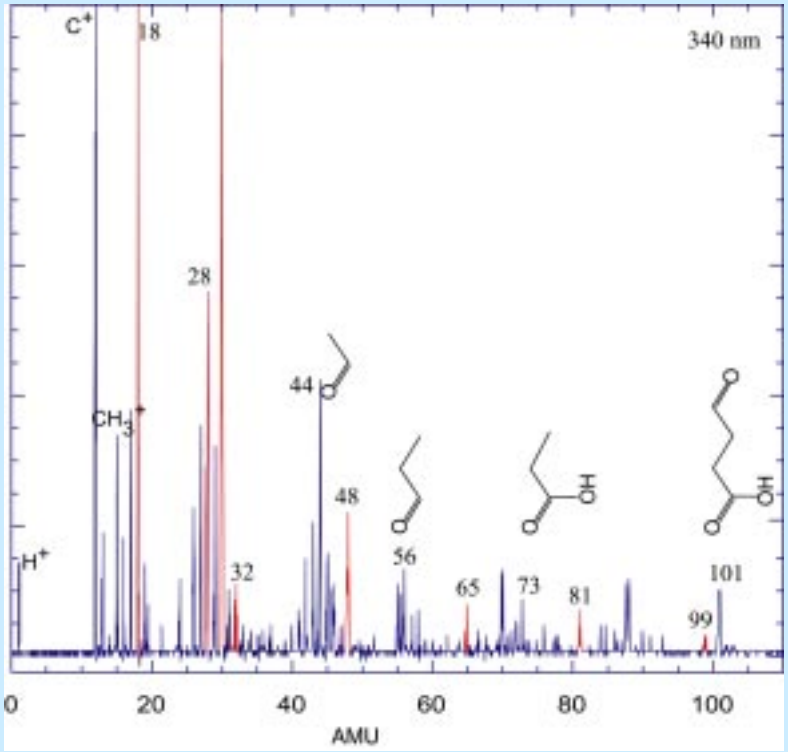


AERODYNAMIC SIZING





MASS SPECTRUM OF AMMONIUM SULFATE/SUCCINIC ACID PARTICLE



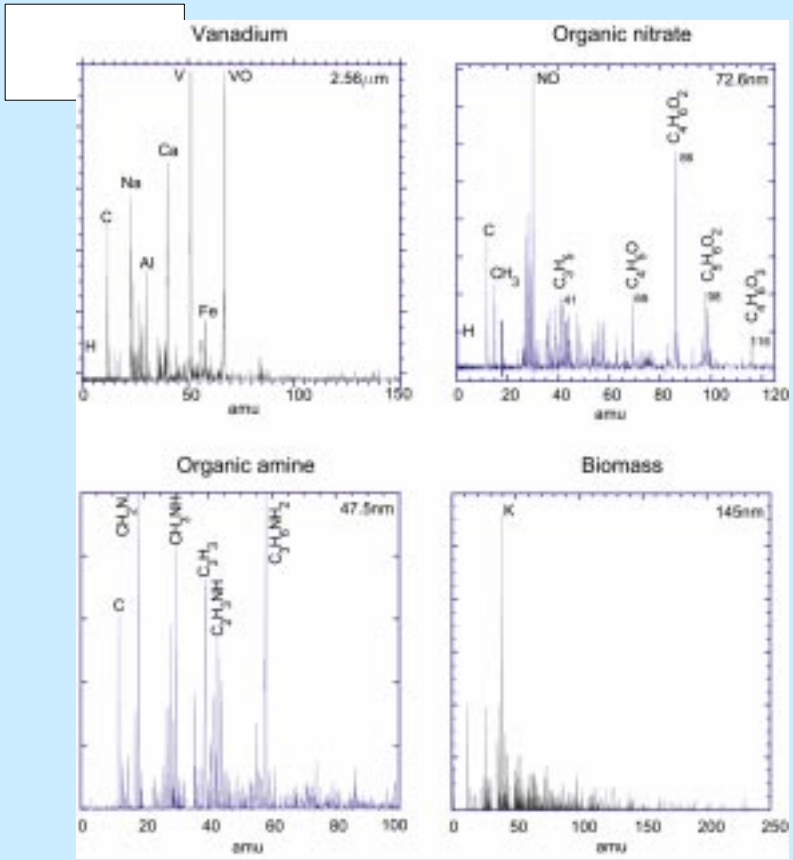
FIELD DEPLOYMENTS

Texas 2000 Air Quality Field Study
Houston Williams Tower (Summer 2000)

Aerosol Characterization Experiment
Cheju Island Korea (Spring 2001)

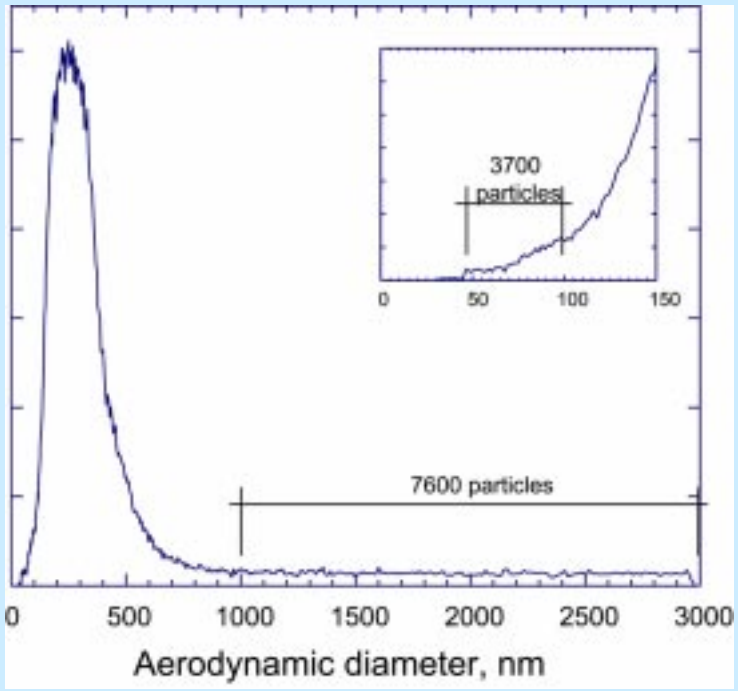
PM2.5 Technology Assessment and
Characterization Study-NY (Summer 2001)

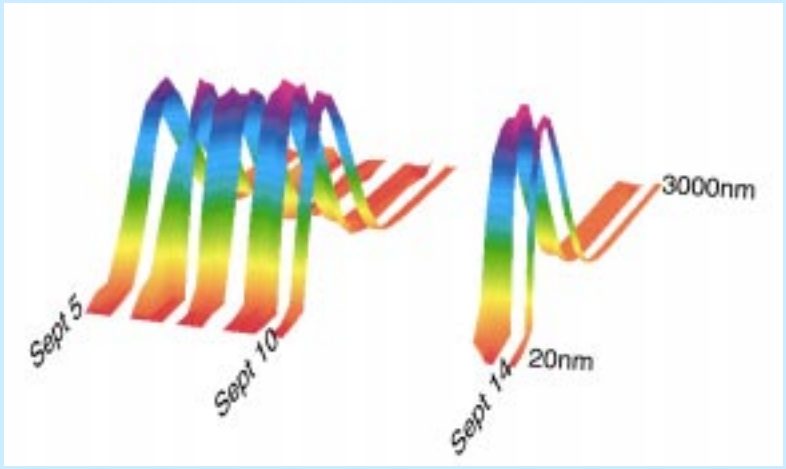
4 little Particles from Texas



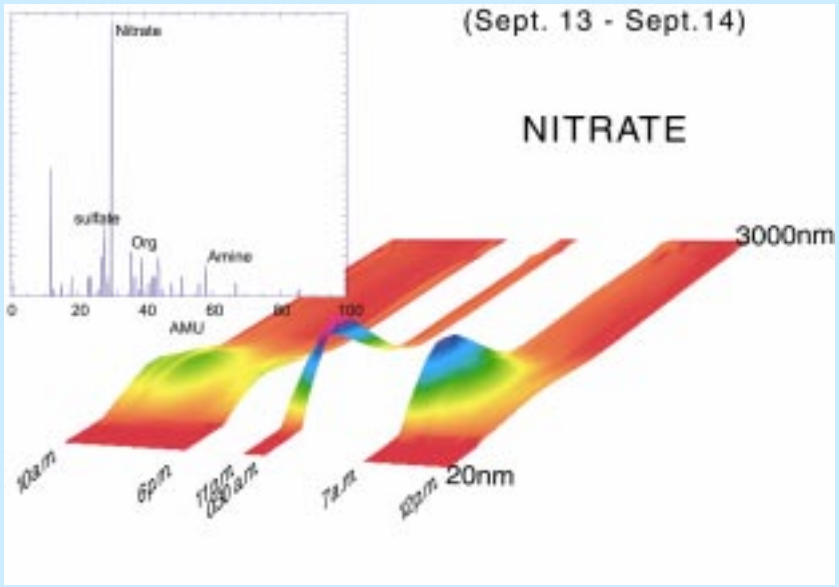
- SPLAT-MS performed very well during its maiden voyage.
- Atmospheric particles are highly variable.
- The smallest particle detected 47.5nm.
- More than half the particles in Houston contain organics.
- More than a third of the particles in Houston contain sulfate.
-

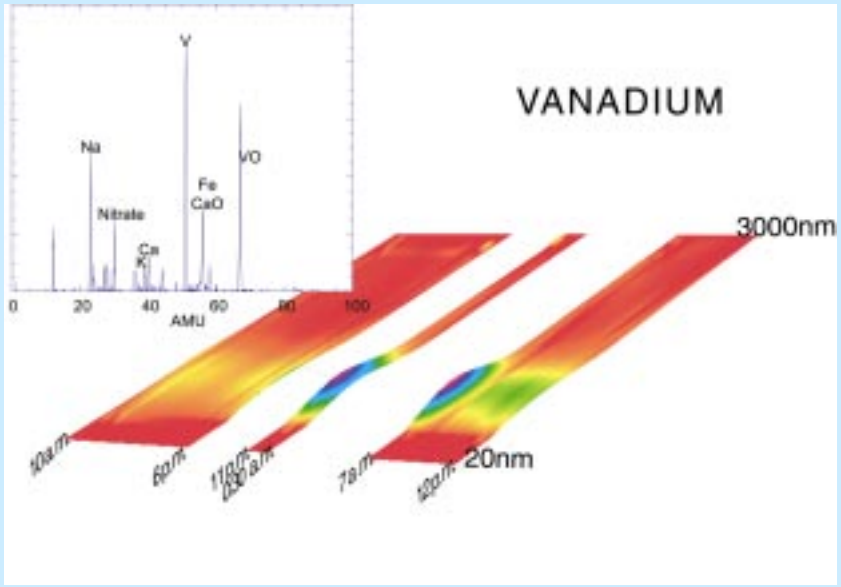
SIZE DISTRIBUTION OF 163,000 PARTICLES FROM HOUSTON (60 HOURS OF DATA COLLECTION)





PRELIMINARY DATA ANALYSIS

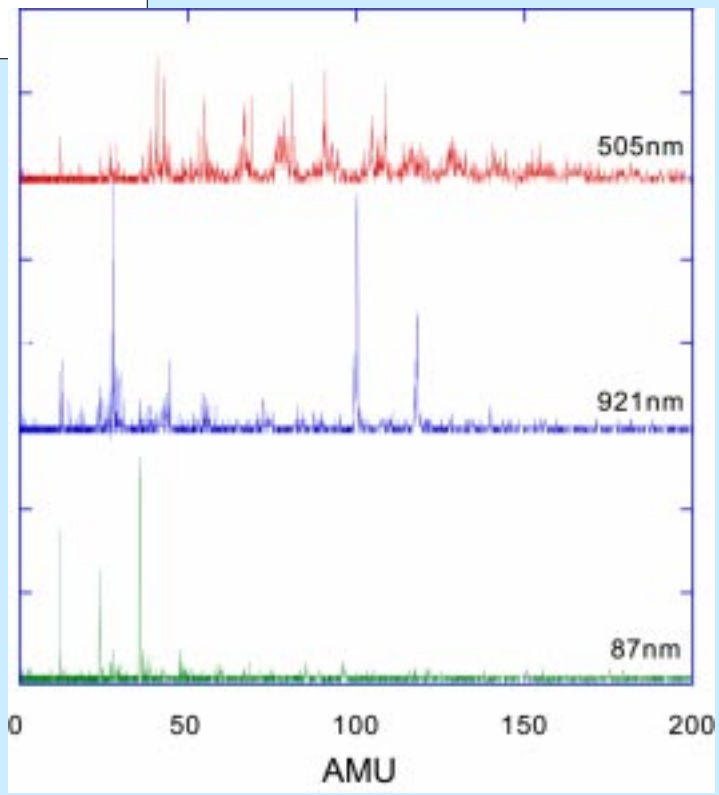


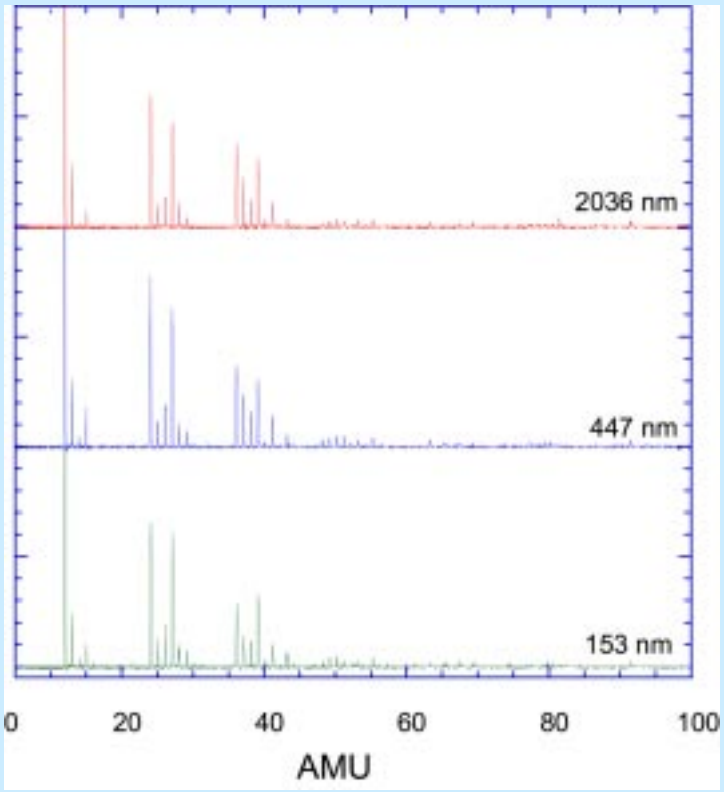


WHERE DO WE GO FROM HERE?

- Technical
  - Better analytical capability
  - Smaller particles
- Data analysis
  - New data visualization techniques
  - Interactive data analysis methods

SEPARATION OF EVAPORATION FROM IONIZATION



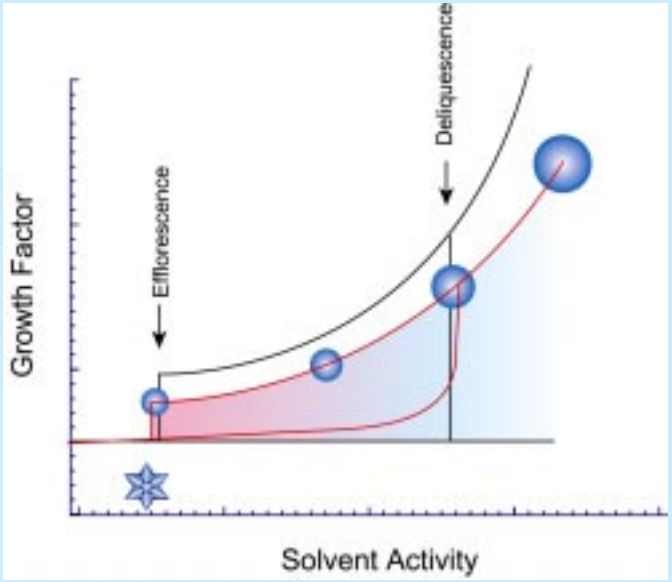


PUSHING the SIZE LIMIT

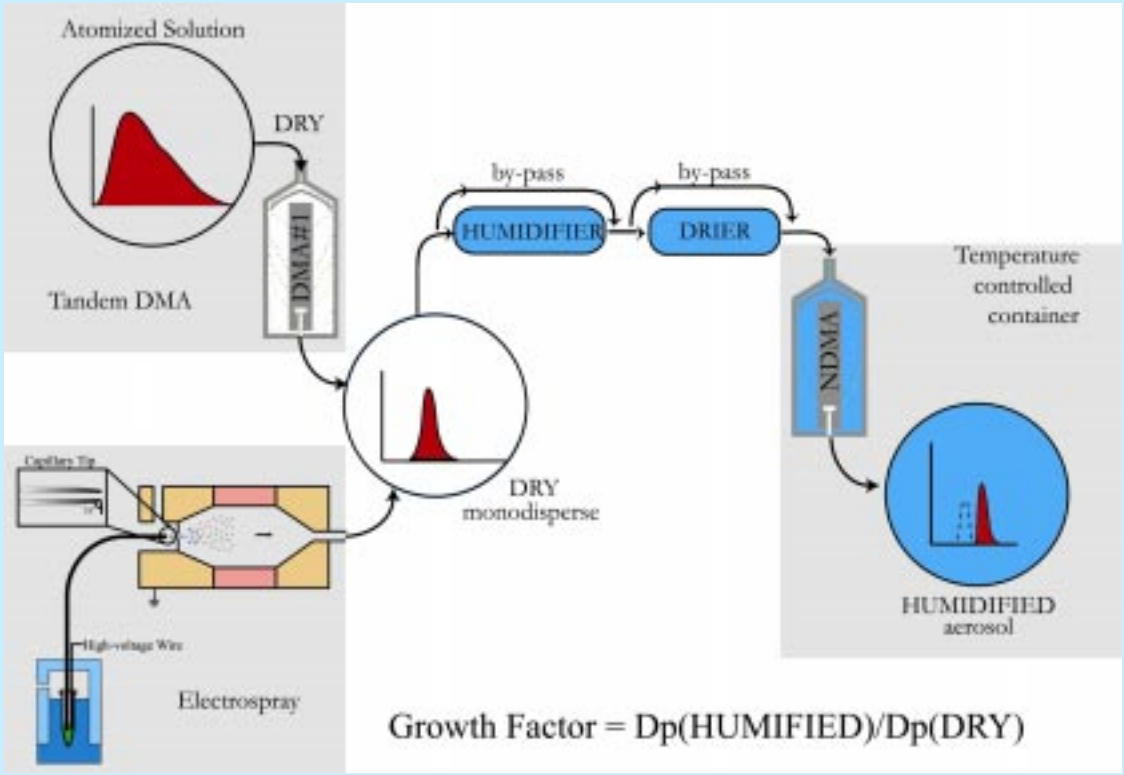
- UV scattering based detection, aerodynamic sizing by TOF, with synchronized evaporation/ionization 40nm
- Aerodynamic sizing by TOF with random evaporation/ionization 20nm
- UV photoionization detection and sizing with synchronized evaporation/ionization 20nm

THERMODYNAMICS and KINETICS on the NANOSCALE

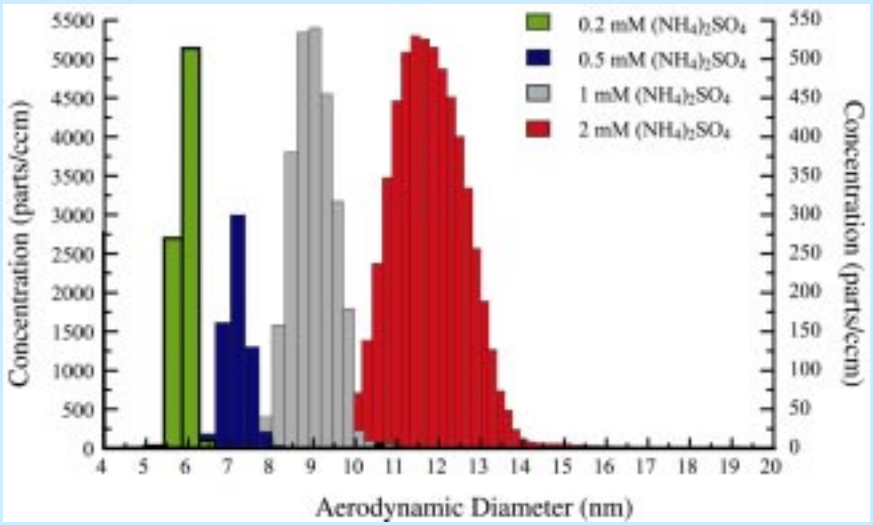
- Understanding the thermodynamics of stable and metastable phases as a function of size
- Investigating the kinetics of first-order phase transitions



EXPERIMENTAL SET-UP

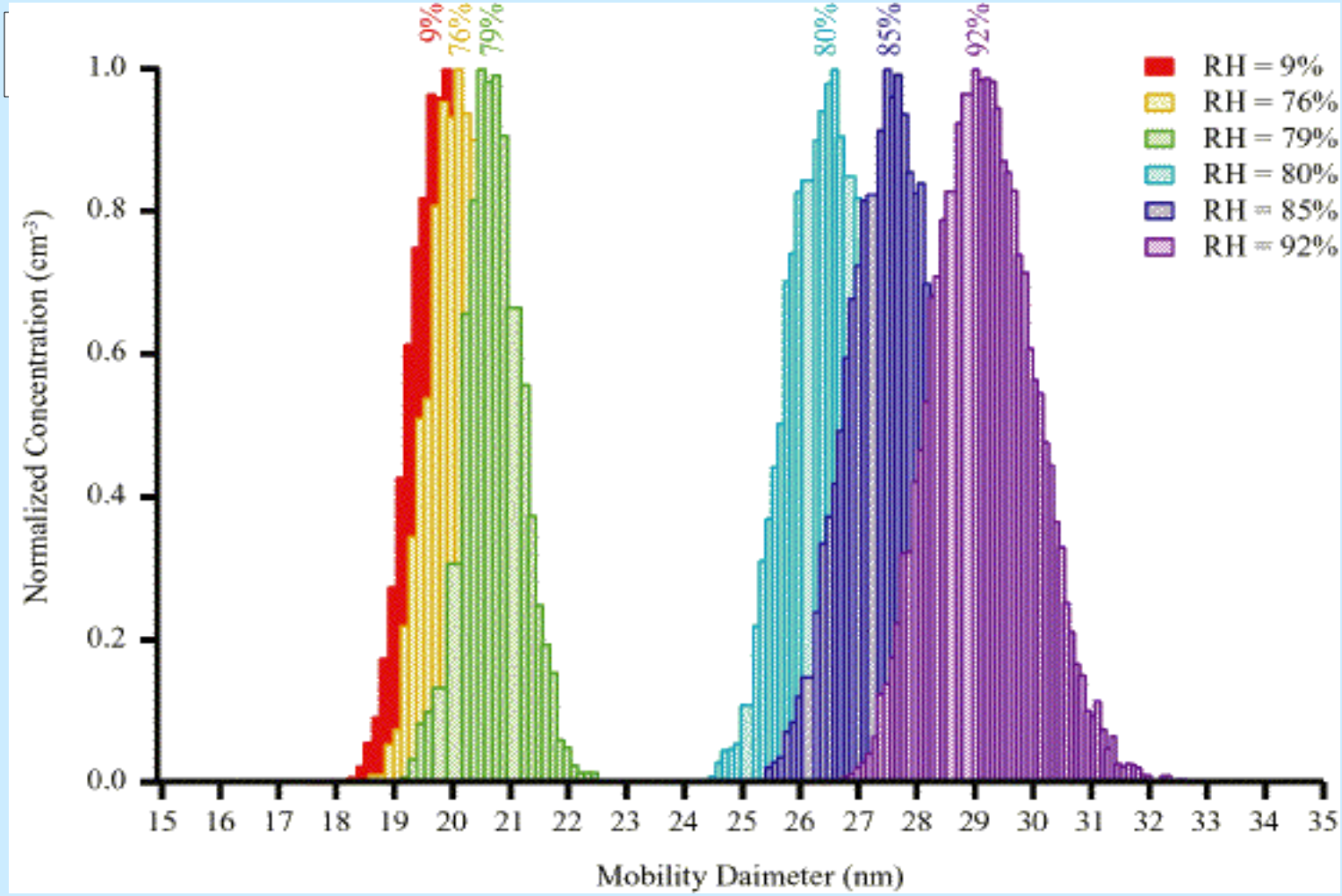


Production of Monodisperse Particles

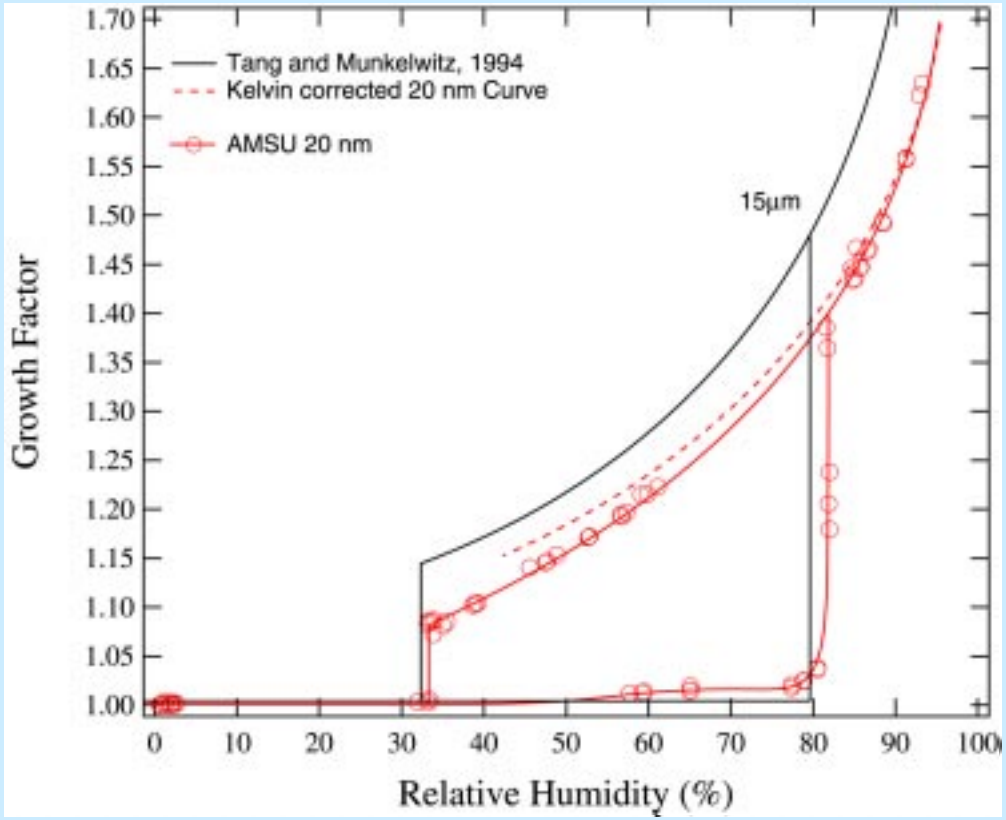


- Monodisperse size distribution.
- High concentration output down to 3 nm sizes.
- Size controlled by the concentration of the electrolytes.

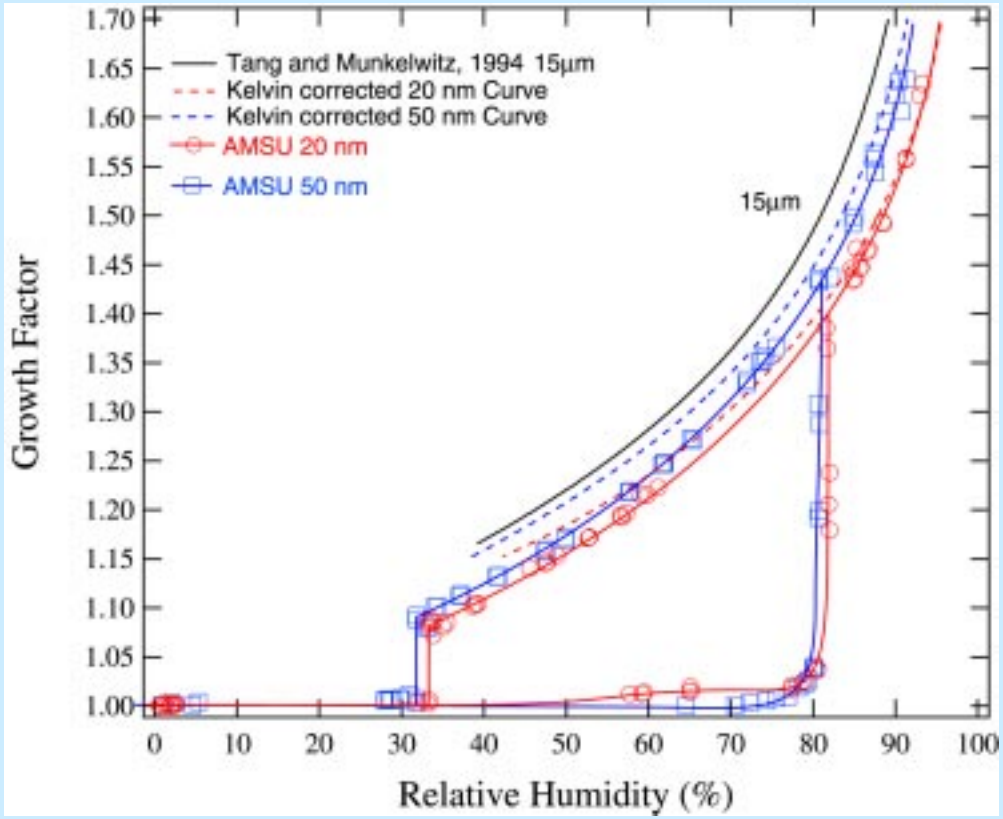
Raw data for 20 nm Ammonium Sulfate Deliquescence



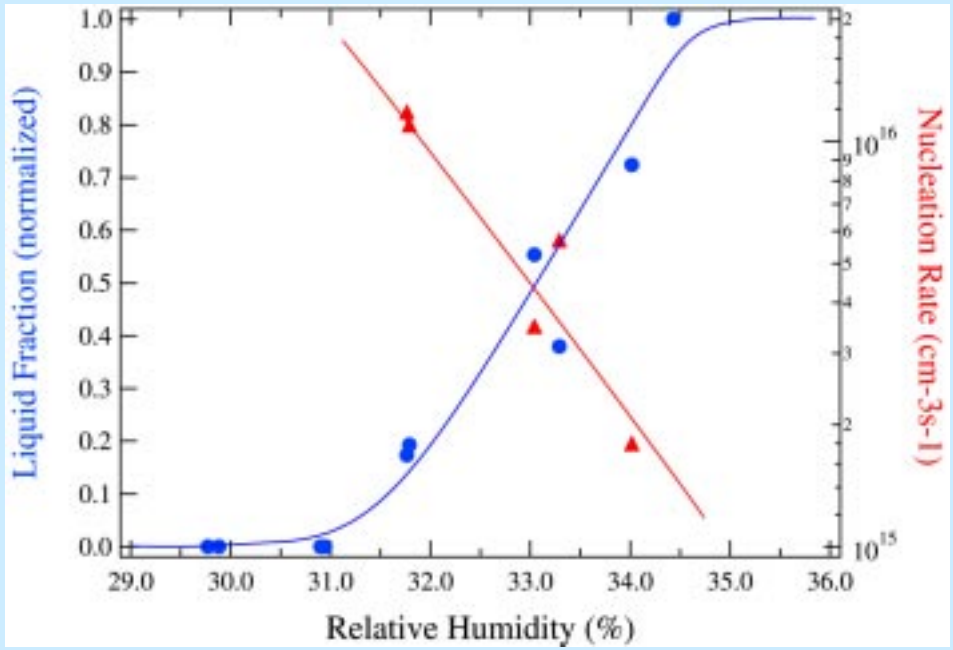
20nm Ammonium Sulfate Particle



20 and 50nm Ammonium Sulfate Particles



Homogeneous Efflorescence Rates of 50 nm AS Particles

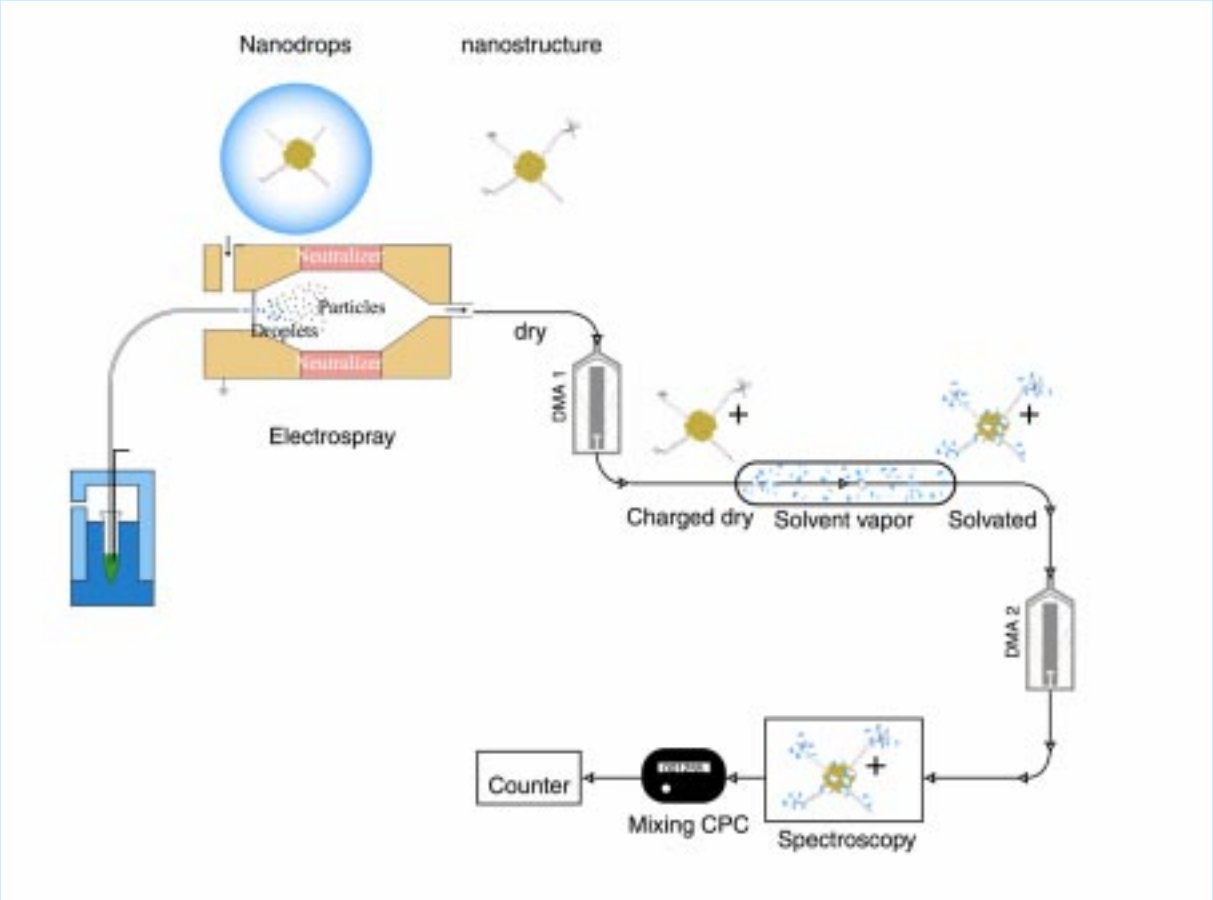


- The normalized fraction of remaining supersaturated solution droplets (Fs) are shown in blue
- The nucleation rates are calculated by

$$J = \frac{-1}{Vt} \ln[F_s]$$

- where J is the rate in $cm^{-3}sec^{-1}$, V is the particle volume and t is the observation time.

Nanoscale Charge Transfer in Molecular Assemblies



Conclusion

- Within the past 2.5 years we have been able to transform both aspects of our microparticle program into the nanometer size range.
- We now have two working systems that consistently produce new data.
- The systems can be applied to a variety of problems DOE related to missions.